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(54) Gas turbine steam addition

Zusatz von Dampf bei einer Gasturbine

Addition de vapeur pour turbine à gaz

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Description

Background of the invention

Field of the Invention - The invention relates to gas turbines. More particularly, it relates to enhancing the output of gas turbines.

Description of the Prior Art - Moisture is often added to gaseous fuels entering combustors as a means of NO_x control. For this purpose, water vapor addition to gas streams is generally accomplished through the direct addition of steam to a gas stream. For gas turbine combustors, fuel gas is commonly injected therein, at pressures in excess of 1379 kPa (200 psia), with said moderate pressure steam providing the moisture needed for NO_x control. The direct addition of steam to the fuel gas serves to provide mass to the fuel gas, which has a beneficial effect on the net power output from the gas turbine, in addition to providing the moisture needed for NO_x control.

In many instances, the steam employed for NO_x control can be more efficiently used in a steam turbine, producing more power than can be obtained by expanding the steam in a gas turbine. For example, 453,6 kg (1000 pounds) per hour at 1724 kPa (250 psia) saturated steam fed to a condensing turbine can produce 83,5 kW (112 hp), while feeding the same amount of steam to an industrial gas turbine will produce about 67,1 kW (90 hp), because of the lower applicable pressure ratio, and require additional fuel to raise the temperature of the steam to that needed for optimum gas turbine operation.

In an alternative approach for adding moisture to a gas stream, a hot water steam is added to the fuel gas by means of a water recirculation loop around a saturation tower from which fuel gas is injected into a gas turbine combustor. The water recirculation loop is heated by recovering heat from a hot fluid by means of a heat exchanger positioned in the loop. The hot water from the loop contacts the process gas stream, i.e., fuel gas, to be moisturised in the saturation tower, which is a packed tower or other device designed to bring the hot water and the process gas stream into intimate contact. In the saturation tower, the heat added in the heat exchanger is removed through vaporization of a portion of the water stream. The vaporized water leaves the top of the saturation tower with the process gas, while the cooled water leaves the bottom of the saturator. A portion of the recirculated water is periodically removed as blowdown to control salt concentrations, and makeup water is added to replace the water lost to the moisturized gas i.e., the fuel gas stream. In the use of such a technique, the fuel gas streams that are to be moisturized need to be located near a source of heat in order to avoid the need for long and expensive water recirculation loops.

EP-A-81 996 discloses an apparatus for the addition of low pressure steam to the fuel gas used to drive a gas turbine comprising a saturation tower adapted for the contacting of said fuel gas with a hot water stream for the moisturization of said fuel gas; conduit means for passing fuel gas to the bottom portion of said saturation tower for upward passage therein; conduit means for passing hot water to the upper portion of said saturation tower for downward passage therein; conduit means for removing moisturized fuel gas from the upper portion of said saturation tower for burning in a gas turbine combustor unit to provide the energy to drive a gas turbine; and conduit means for withdrawing water from the bottom portion of said saturation tower, said conduit means and the conduit means for passing hot water to the saturation tower being in fluid communication and forming a water recirculation loop around said saturation tower.

While such approaches are useful for achieving a desired moisturizing of gas streams, there remains a desire in the art for further improvements. Thus, the moderate or high pressure steam used in one approach or the long water recirculation loops frequently required in the other, represent elements of expense that desirably should be reduced to achieve the ever-increasing overall requirements for practical gas turbine applications.

It is an object of the invention, therefore, to provide an improved apparatus for such gas turbine applications.

It is another object of the invention to provide an apparatus for more efficiently operating industrial gas turbines.

With these and other objects in mind, the invention is hereinafter described in detail, the novel features thereof bring particularly pointed out in the appended claims.

Summary of the Invention

The output of gas turbines is enhanced using low pressure steam. A pumped water circuit and water contact tower are used to achieve desired gas moisturization using such low pressure steam.

Brief Description of the Drawings

The invention is hereinafter described with reference to the accompanying drawings in which:

Fig. 1 is a process flow diagram of an embodiment of the invention for low pressure level addition of steam to a fuel gas;

Fig. 2 is a process flow diagram of another embodiment of the invention illustrating said low pressure steam addition with heat exchange;

Detailed Description of the Invention

The objects of the invention are accomplished by employing means to enhance the output of a gas turbine using low pressure steam, thereby enabling energy to

be advantageously conserved. By the use of a pumped water circuit and a water contact tower, gas moisturization can be achieved using low pressure steam, for gas turbine fuel.

In the practice of the invention, a water recirculation loop similar to that used in recovering heat from a hot process stream is employed. The heat required for moisturizing the process gas stream, e.g. fuel gas to a gas turbine, is provided either by direct injection of steam into the recirculation loop water or by heat exchange with steam. In either case, the steam will have a pressure only slightly above the partial pressure of water vapor in the moisturized gas stream.

The benefits derived from the invention are illustrated by consideration of a moderate pressure gas stream, e.g. 1724 KPa (250 psia), desired to have a moisture content of 10%. For a stream of 226.8 kg/hr (500 lb. moles/hr.) of dry gas at 1724 kPa (250 psia), approximately 453,6 kg/hr (1,000 lb/hr) of steam is needed to produce a gas mixture containing 10 mol of water vapor. If direct steam addition to said gas stream is employed, 1724 kPa (250 psia) is the minimum pressure of saturated steam that can be used to achieve the 10% moisture addition level.

Alternatively, the 1724 kPa (250 psia) saturated steam could be used in a condensing steam turbine to produce 83,5 kW (112 hp). By contrast, the invention enables the use of approximately 276 kPa (40 psia) saturated steam to achieve the same moisture level of 10% in the 1724 kPa (250 psia) gas stream. The desirability of using 276 kPa (40 psia) steam will be apparent since only about 54,4 kW (73 hp) can be generated per 453,6 kg/hr (1,000 lb/hr) of steam at this pressure level. Consequently, for a highly efficient, intergrated steam system, the equivalent of 29,1 kW (39 hp), or nearly 35% 25 less useable energy, is required to moisturize the gas stream by use of the invention as compared to the requirements of direct steam addition to the gas stream.

With reference to Fig. 1 of the drawings, 30 the low-level steam moisture addition of the invention is shown in conjunction with a gas turbine employed for electric power generation. In this illustrated embodiment, fuel for driving a combustion turbine is passed in line 1 to the bottom of saturation tower 2 in which it is heated and its moisture level is raised to 10% in countercurrent contact with hot water passing to the upper, vapor portion of said tower from recirculation line 3. The thus-treated fuel gas removed from the upper portion of tower 2 is passed in line 4 for burning in gas turbine combustor unit 5 to provide the energy to drive gas turbine 6. The somewhat cooler water removed from the bottom of said tower 2 in line 7 is throttled across valve 8 to a pressure sufficiently low to permit injection therein of low pressure steam. A small portion of the water flow in recirculation line 7 is removed through line 9 to control the buildup of harmful salts in the recirculation loop comprising said recirculation lines 3 and 7. Low-pressure steam for replacement purposes is added to recirculation line 7 from steam supply line 10. Such steam addition serves to raise the temperature of the water in the recirculation loop and provide the mass of water needed to sustain the moisturization operation. The hot water in recirculation line 7 downstream of the steam addition point is pumped by means of pump 11 at a pressure sufficiently high for delivery in line 3 to tower 2. Gas from gas turbine combustor 5 is passed in line 12 to gas turbine 6 connected by drive shaft 13 to air compressor 14 to which feed air is passed in line 15. A portion of the compressed air removed from air compressor 14 is passed in line 16 to said combustor 5, while the remaining portion of said compressed air is passed in line 17 to the inlet end of gas turbine 6. Exhaust gas from the gas turbine is removed in line 18. The power generated by gas expansion in said gas turbine is also used to generate electrical power in generator 19 driven by shaft 20 connected to said gas turbine 6.

In the alternative embodiment of the invention shown in Fig. 2, the system as shown in Fig. 1 is employed with the desired heat of vaporization being supplied to the recirculating water by low-pressure steam across a heat exchanger rather than by direct injection. Thus, low-pressure steam in line 10 passes to heat exchanger 21, with the low-pressure condensate formed therein being pumped through line 10A, containing pump 22, for injection into line 7 of the water recirculation loop. Upon passing to pump 11, the water in said line 7 is heated in said heat exchanger 21 before being recycled in line 3 to saturation tower 2. In this embodiment, the water recirculation loop will be seen to perform as in the Fig. 1 embodiment except with respect to pump 11. Because there is no need to reduce the pressure on the recirculation loop to allow low-pressure steam injection therein, since said steam is condensed in heat exchanger 21, pump 11 is needed only to raise the pressure of the recirculating water in line 7 a small amount to overcome the pressure drop in the water recirculation loop. Consequently, the energy used by pump 11 will be much less in the Fig. 2 embodiment than in the Fig. 1 embodiment.

Those skilled in the art will appreciate that variations can be made in the details of the invention as carried out in practice without departing from the scope of the invention as set forth in the appended claims. For purposes of the invention, low pressure steam addition to the water in the recirculation loop will be understood to be such addition at a pressure of from about 138 kPa about 690 kPa (about 20 psia to about 100 psia), with a steam addition pressure of preferably from about 276 kPa to 414 kPa (about 40 to 60 psia), conveniently about 345 kPa (50 psia), although low pressures outside such ranges can also be employed in the practice of the invention.

The invention will be seen to represent a significant advance in the field of gas turbine operations. The use of low pressure steam to enhance the output of a gas turbine advantageously enables desirable energy con-

servation to be achieved.

Claims

1. An apparatus for the addition of low pressure steam to the fuel gas used to drive a gas turbine comprising:

   (a) a saturation tower (2) adapted for the contacting of said fuel gas with a hot water stream for the moisturization of said fuel gas;
   (b) conduit means (1) for passing fuel gas to the bottom portion of said saturation tower (2) for upward passage therein;
   (c) conduit means (3) for passing hot water to the upper portion of said saturation tower (2) for downward passage therein;
   (d) conduit means (4) for removing moisturized fuel gas from the upper portion of said saturation tower (2) for burning in a gas turbine combustor unit (5) to provide the energy to drive a gas turbine (6);
   (e) conduit means (7) for withdrawing water from the bottom portion of said saturation tower (2), said conduit means and the conduit means (3) for passing hot water to the saturation tower being in fluid communication and forming a water recirculation loop around said saturation tower;

   characterized in that the hot water enters the saturation tower (2) in liquid form; and in that the apparatus further comprises:

   (f) pump means (11) in the water recirculation loop for pumping said water therein for delivery to the saturation tower (2);
   (g) valve means (8) in said water recirculation loop upstream of said pump means (11) for throttling the pressure of the water withdrawn from the saturation tower (2) to a pressure such as to enable low pressure steam to be injected therein; and
   (h) steam supply conduit means (10) for the addition of low pressure steam to the water recirculation loop at a point intermediate said pump means (11) and said valve means (8);

   whereby moisturization of the fuel gas for a gas turbine is advantageously achieved using low pressure steam.

2. The apparatus of claim 1 and including conduit means (9) for removing a portion of the water in said water recirculation loop.

3. The apparatus of claim 1 and including heat exchange means (21) positioned in said water recirculation loop downstream of said pump means (22), said heat exchange means adapted to heat the water in the water recirculation loop by means of said low pressure steam from said steam supply conduit means (10), and pump means (22) for pumping low-pressure condensate formed upon cooling of said low pressure steam to said water recirculation loop at a point intermediate said pump means and said valve means (8).

Revendications

1. Appareil pour l'addition d'une vapeur d'eau à basse pression au gaz combustible utilisé pour l'entraînement d'une turbine à gaz, comportant :

   (a) une tour (2) de saturation destinée à la mise en contact dudit gaz combustible avec un courant d'eau chaude pour l'humidification dudit gaz combustible ;
   (b) un moyen à conduit (1) pour amener du gaz combustible à la partie de fond de ladite tour (2) de saturation afin qu'il s'élève dans celle-ci ;
   (c) un moyen à conduit (3) pour amener de l'eau chaude à la partie supérieure de ladite tour (2) de saturation afin qu'elle descende dans celle-ci ;
   (d) un moyen à conduit (4) pour enlever du gaz combustible humidifié de la partie supérieure de ladite tour (2) de saturation afin qu'il brûle dans un bloc de combustion (5) d'une turbine à gaz pour produire l'énergie pour l'entraînement d'une turbine à gaz (6) ;
   (e) un moyen à conduit (7) destiné à soutirer de l'eau de la partie de fond de ladite tour (2) de saturation, ledit moyen à conduit et le moyen à conduit (3) pour amener de l'eau chaude à la tour de saturation étant en communication de fluide et formant une boucle de recirculation d'eau autour de ladite tour de saturation ;

   caractérisé en ce que l'eau chaude entre dans la tour (2) de saturation sous forme liquide, et en ce que l'appareil comporte en outre :

   (f) un moyen à pompe (11) dans la boucle de recirculation d'eau pour pomper ladite eau afin de l'amener à la tour (2) de saturation ;
   (g) un moyen à vanne (8) dans ladite boucle de recirculation d'eau, en amont dudit moyen à pompe (11), pour abaisser par étranglement la pression de l'eau soutirée de la tour (2) de saturation jusqu'à une pression permettant à de la vapeur d'eau à basse pression d'y être injectée ; et
   (h) un moyen (10) à conduit d'alimentation en vapeur d'eau pour l'addition de vapeur d'eau à

basse pression à la boucle de recirculation d'eau en un point situé entre ledit moyen à pompe (11) et ledit moyen à vanne (8) ;

grâce à quoi une humidification du gaz combustible pour une turbine à gaz est obtenue avantageusement en utilisant de la vapeur d'eau à basse pression.

2. Appareil selon la revendication 1 et comprenant un moyen à conduit (9) pour enlever une partie de l'eau se trouvant dans ladite boucle de recirculation d'eau.

3. Appareil selon la revendication 1 et comprenant un moyen (21) d'échange de chaleur positionné dans ladite boucle de recirculation d'eau en aval dudit moyen à pompe (22), ledit moyen d'échange de chaleur étant destiné à chauffer l'eau dans la boucle de recirculation d'eau au moyen de ladite vapeur d'eau à basse pression provenant dudit moyen (10) à conduit d'alimentation en vapeur d'eau, et un moyen à pompe (22) pour pomper un condensat à pression formé lors du refroidissement de ladite vapeur d'eau à basse pression vers ladite boucle de recirculation d'eau en un point situé entre ledit moyen à pompe et ledit moyen à vanne (8).

Patentansprüche

1. Vorrichtung für das Zusetzen von Niederdruckdampf zu Brenngas, welches zum Antreiben einer Gasturbine benutzt wird, versehen mit:

a) einem Sättigungsturm (2) zum Inkontaktbringen des Brenngases mit einem Heißwasserstrom zwecks Befeuchten des Brenngases;
b) einer Leitungsanordnung (1) zum Zuleiten von Brenngas zu dem unteren Teil des Sättigungsturmes (2), so daß dieses darin nach oben strömt; c) einer Leitungsanordnung (3) zum Zuleiten von heißem Wasser zu dem oberen Teil des Sättigungsturmes (2), so daß dieses darin nach unten strömt;
d) einer Leitungsanordnung (4) zum Abziehen von befeuchtetem Brenngas von dem oberen Teil des Sättigungsturmes (2), um dieses in einer Gasturbinen-Verbrennungseinheit (5) zu verbrennen, um die für das Antreiben einer Gasturbine (6) benötigte Energie zu liefern;
e) einer Leitungsanordnung (7) zum Abziehen von Wasser von dem unteren Teil des Sättigungsturmes (2), wobei diese Leitungsanordnung und die Leitungsanordnung (3) zum Zuleiten von heißem Wasser zu dem oberen Teil des Sättigungsturmes in Fluidverbindung stehen und eine Wasserumwälzschleife um den Sättigungsturm herum bilden;

dadurch gekennzeichnet, daß das heiße Wasser in flüssiger Form in den Sättigungsturm (2) gelangt und die Vorrichtung ferner versehen ist mit:

f) einer Pumpanordnung (11) in der Wasserumwälzschleife zum Pumpen des darin befindlichen Wassers zwecks Einspeisung in den Sättigungsturm (2);
g) einer Ventilanordnung (8) in der Wasserumwälzschleife stromauf von der Pumpanordnung (11) zum Drosseln des Drucks des von dem Sättigungsturm (2) abgezogenen Wassers auf einen Druck, welcher das Einleiten von Niederdruckdampf in dieses zuläßt; und
h) einer Dampfzufuhr-Leitungsanordnung (10) für das Zusetzen von Niederdruckdampf zu der Wasserumwälzschleife an einer zwischen der Pumpanordnung (11) und der Ventilanordnung (8) liegenden Stelle;

wodurch das Befeuchten des Brenngases für eine Gasturbine vorteilhaft unter Verwendung von Niederdruckdampf erreicht wird.

2. Vorrichtung nach Anspruch 1, ferner versehen mit einer Leitungsanordnung (9) zum Entfernen eines Teils des in der Wasserumwälzschleife befindlichen Wassers.

3. Vorrichtung nach Anspruch 2, ferner versehen mit einer in der Wasserumwälzschleife stromab von der Pumpanordnung (11) angeordneten Wärmetauscheranordnung (21), die dafür ausgelegt ist, das Wasser in der Wasserumwälzschleife mittels des Niederdruckdampfes von der Dampfzufuhr-Leitungsanordnung (10) zu erwärmen, sowie mit einer Pumpanordnung (22), um beim Abkühlen des Niederdruckdampfes gebildetes Niederdruck-Kondensat zu der Wasserumwälzschleife an einer zwischen der erstgenannten Pumpanordnung und der Ventilanordnung (8) liegenden Stelle zu pumpen.

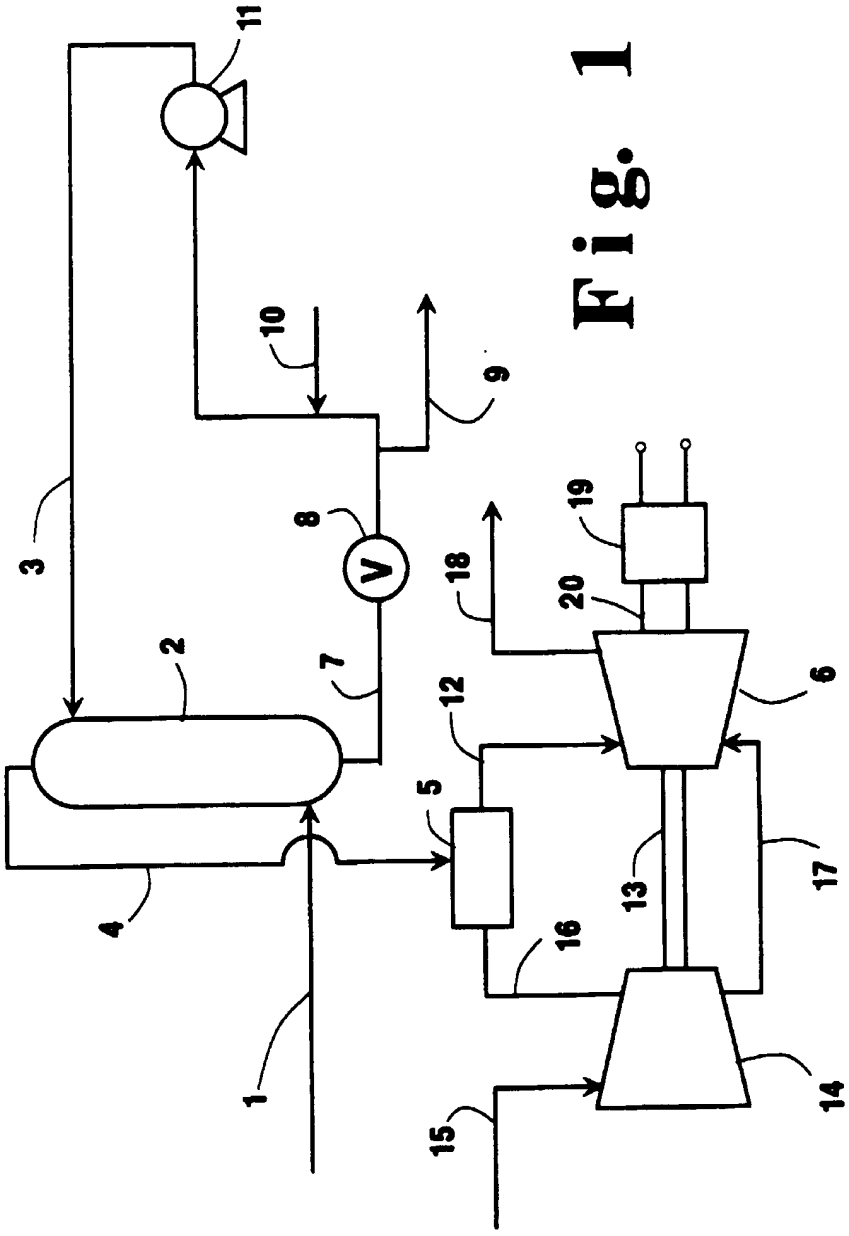

Fig. 1

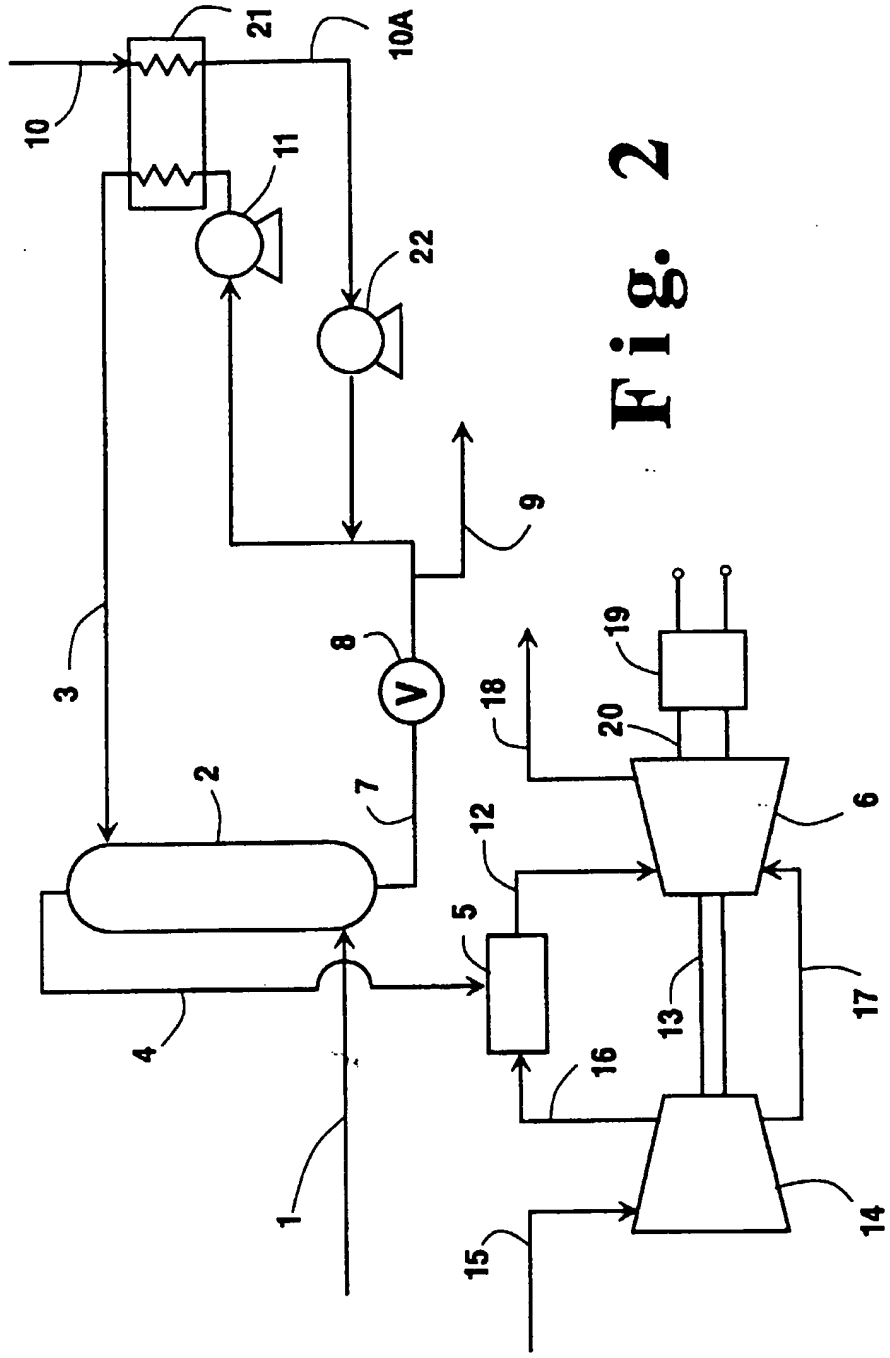

Fig. 2